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From Chile to the South African west coast: first reports of the Chilean stone crab *Homalaspis plana* (H. Milne Edwards, 1834) and the South American sunstar *Heliaster helianthus* (Lamarck, 1816) outside their natural ranges

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Abstract

The South American multiradiate sunstar *Heliaster helianthus* (Lamarck, 1816) and the Chilean stone crab *Homalaspis plana* (H. Milne Edwards, 1834) are marine predators that, previous to this report, have no invasion history. However, during subtidal maintenance of a pier within Saldanha Bay along the South African west coast during 2015–2017, a single individual of each species was detected on the seafloor. Following this, intertidal and subtidal surveys were undertaken in surrounding natural habitats, but no further individuals were recorded. Both species are native to Chile, a region with very similar environmental conditions to the west coast of South Africa and from which other South African marine alien species originate, highlighting the connectedness between these regions and the risk for future transfers and establishment. The presence of two pathways from Chile to South Africa (shipping and aquaculture imports) and closely matching environmental conditions are likely to play a role in future successful introductions of Chilean species to the South African west coast. It is, therefore, recommended that particular attention be paid to monitoring aquaculture imports from the west coast of South America and that incoming vessels from that region be inspected upon arrival. Additionally, both *H. heliaster* and *H. plana* should be added to alien species watchlists in South Africa and other regions connected to Chile via marine vectors and which experience similar environmental conditions.

Key words: aquaculture, Crustacea, Echinodermata, introductions, marine alien species, shipping

Introduction

Marine alien species are recognised as an important threat to biodiversity (Molnar et al. 2008). Nonetheless, following increases in global trade and connectedness, the rate of invasions continues to rise (Seebens et al. 2013), highlighting the need for a better understanding of the drivers of successful invasions. Despite the complexities associated with invasion success (Hayes and Barry 2008), in the absence of other reliable approaches, invasion history is often used as a basis for predicting future invasion success (e.g., Zaiko et al. 2014). The South American multiradiate sunstar *Heliaster helianthus* (Lamarck, 1816) and the Chilean stone crab *Homalaspis plana* (H. Milne Edwards, 1834) are two species that have no reported invasion history and neither has been highlighted as a species likely to spread outside of its natural range along the west coast of South America.

Heliaster helianthus is a predatory seastar native to intertidal and shallow subtidal waters of northern and central Chile and southern Peru (Castilla and Paine 1987). Adults can grow up to 40 arms (Madsen 1956) and reach diameters of more than 20 cm (Barahona and Navarrete 2010). The species reproduces sexually through external fertilisation (Castilla et al. 2013) and has long distance dispersal abilities due to long-lived planktotrophic larvae (Navarrete and Manzur 2008). The growth rate of *H. helianthus* is slow but variable (Barrios et al. 2008; Manzur et al. 2010). These seastars are fierce predators, feeding predominantly on local mussels *Perumytilus purpuratus* (Lamarck, 1819) and *Semimytilus algosus* (Gould, 1850) (Tokeshi 1989), but can shift their diet to other prey when mussels occur at low abundances (Barahona and Navarrete 2010). *Heliaster helianthus*, therefore, plays a fundamental role in the community structure of wave exposed, intertidal rocky shores as a keystone species in its native region (Paine et al. 1985; Navarrete and Manzur 2008). Whilst *H. helianthus* is largely free of predators in the intertidal zone, the species is predated upon in shallow subtidal habitats by the seastar *Meyenaster gelatinosus* (Meyen, 1834) (Gaymer and Himmelman 2008) and, to a lesser extent, the rockfish *Graus nigra* (Philippi, 1887) (Fuentes 1982) and *Homalaspis plana* (Castilla 1981).

Homalaspis plana occurs all along the Chilean coast (Morales and Antezana 1983), forming part of an important artisanal fishery in the region (Fernández and Castilla 2000). However, little is known about its life history, habitat preferences or recruitment dynamics (Fernández and Castilla 2000). *Homalaspis plana* has a peak settlement period during the austral summer, and crab densities differ among habitat and substrate types. Juveniles occur predominantly in sheltered habitats, particularly in sand with boulders, shell hash with boulders and rock platforms with boulders (Fernández and Castilla 2000). The presence of polychromatism (i.e. having various or changing colours) in juvenile *H. plana* may protect them from predation when they are small and vulnerable (Fernández and Castilla 2000). *Homalaspis plana* has a generalist diet, with adult crabs known to feed on the crab *Petrolisthes tuberculatus* (Guérin, 1835), barnacle *Balanus laevis* (Bruguière, 1789), mussel *S. algosus* and gastropod *Tegula atra* (Lesson, 1830), although they demonstrate a preference for other crustaceans (Morales and Antezana 1983).

The present study is the first to report both *H. helianthus* and *H. plana* as introduced species. It describes their detection in a bay along the west coast of South Africa and discusses the implications of their successful transport to the region.

Methods

Saldanha Bay is located along the west coast of South Africa (33º01′23.83″S; 17º57′10.10″E) (Figure 1). The shoreline of the bay comprises mostly sandy shores, interspersed with rocky headlands. The shallow Langebaan Lagoon, an important conservation area, extends from its southern margin. The bay is a hub of commercial activity, accommodating a commercial fishing harbour, an iron ore export terminal, an oil and gas infrastructure maintenance facility, multiple aquaculture operations and numerous marinas. During routine maintenance of a pier within the bay (see "Detection site" in Figure 1), two unusual species were detected on the seafloor. This area was dominated by a sandy bottom but had rocks present under the pier. The first, detected during August 2015, was a single, large, adult seastar while the second was a single, purple coloured male crab, detected during February 2017. The species were subsequently confirmed to be the South American multiradiate sunstar *Heliaster helianthus* and the Chilean stone crab *Homalaspis plana*, respectively. Identifications via morphological examination were undertaken following Madsen (1956), Viviani (1978) and Castilla et al. (2013) for *H. helianthus* and Thoma et al. (2012) for *Homalaspis plana.*

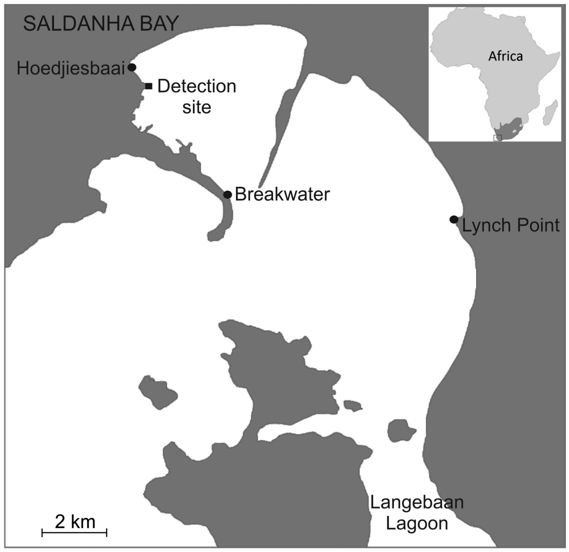

Figure 1. Saldanha Bay situated along the west coast of South Africa. The site at which *Heliaster helianthus* and *Homalaspis plana* were recorded (Detection site), along with the sites at which subsequent surveys were undertaken (i.e. Breakwater, Hoedjiesbaai and Lynch Point).

As these species were alien to South Africa, subsequent intertidal and subtidal surveys were undertaken in the surrounding natural rocky habitats. Three sites providing good coverage of sheltered rocky habitats were surveyed (Figure 1). As these species occur on sandy shores with boulders and rocky shores, and sandy boulder shores are absent from the bay, only rocky shores were surveyed. These were Breakwater (33º02′6.01″S; 17º58′20.07″E), Hoedjiesbaai (33º00′67.16″S; 17º94′63.39″E) and Lynch Point (33º02′38.37″S; 18º02′9.59″E). Surveys were undertaken in March 2016, following the discovery of the starfish, and in March 2018, after the crab was detected. At each site, 45 min intertidal and subtidal

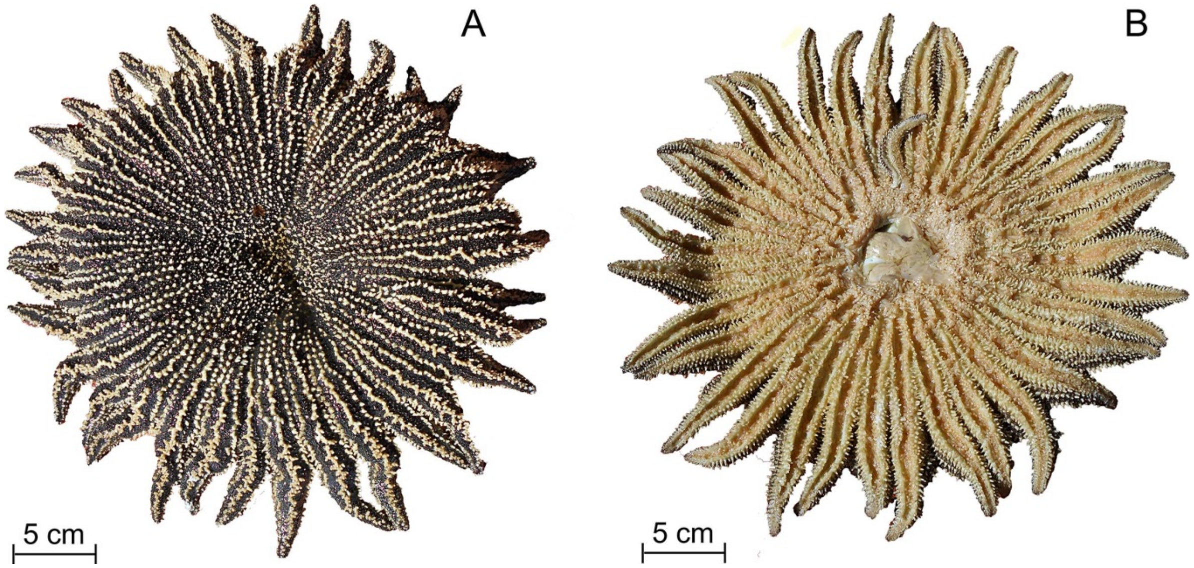

Figure 2. A) Dorsal and B) ventral views of an adult South American multiradiate sunstar *Heliaster helianthus,* detected in the subtidal zone in Saldanha Bay, South Africa. Photograph by T.B. Robinson.

surveys were completed by two researchers. Intertidal surveys included searching all rocky areas for the seastar and crab, including overturning boulders. Subtidal surveys (down to 10 m) included all potential habitats, including around boulders and kelp holdfasts.

Results

Despite additional surveys, only the original single individuals of each species (*Heliaster helianthus* and *Homalaspis plana*) were detected. Based on their large size, both individuals were considered adults. Both individuals appeared in good health and showed no signs of physiological stress.

Species from the genus *Heliaster* are characterised by a large disc and a large number of rays (Castilla et al. 2013). Adult *H. helianthus* typically have 30–40 rays supporting arms that are free for approximately 30–50% of its body (Madsen 1956). The *H. helianthus* individual detected was 33.42 cm in diameter and had 35 arms (Figure 2). The ventral surface supported a single smaller arm, most likely representative of arm regeneration, which is common in this genus (Viviani 1978).

Species in the genus *Homalaspis* are distinguished from other genera in the family by differences in the characteristics of the carapace, frontal margin, inner supraorbital tooth, anterolateral teeth and epistome (Thoma et al. 2012). Based on the detailed description of *Homalaspis plana* provided by Thoma et al. (2012), we were able to confirm the identification of the individual detected. This crab had a carapace width of 6.45 cm, was a male and had distinctive purple colouration with markings on the carapace (Figure 3).

Figure 3. Adult male Chilean stone crab *Homalaspis plana* detected in the subtidal zone in Saldanha Bay, South Africa. Photograph by K. Peters.

Discussion

Over the last 14 years, six new alien species have been reported in Saldanha Bay (Table 1), including the two species detected during this study. Of these species, three are native to Chile and Peru, highlighting the threat of introductions from this region. Notably, an additional Chilean species, the sea urchin *Tetrapygus niger* (Molina, 1782), has been recorded further

Table 1. Alien species recorded for the first time in Saldanha Bay (SB) between 2004 and 2017.

Taxa	Native range	Year of discovery in SB	Reference	Probable Vector/Pathway	Population status
Amphipoda					
Caprella mutica	Japan	2015	Peters and Robinson 2017	Ballast water/Hull fouling	Stable population on yachts
Decapoda					
Homalaspis plana	Chile	2017	Present study	Ballast water/Hull fouling	One individual (removed)
Porcellana africana	Mediterranean Sea and eastern Atlantic	2012	Griffiths et al. 2018	Shipping	Stable populations in SB
Pinnixa occidentalis	North America	2004	Clark and Griffiths 2012	Shipping	Stable populations in SB
Bivalvia					
Semimytilus algosus	Chile	2009	de Greef et al. 2013	Aquaculture/Shipping	Stable populations in harbours and along natural coastline
Asteroidea					
Heliaster helianthus	Chile and southern Peru	2015	Present study	Ballast water/Hull fouling	One individual (removed)

north than Saldanha Bay (Haupt et al. 2010), although that population has subsequently died out (Mabin et al. 2015). Additionally, the prey species from the native range of both the seastar *Heliaster helianthus* and the crab *Homalaspis plana* (i.e. the mussel *Semimytilus algosus*) is already present in the bay. This high number of Chilean species present along the South African west coast likely reflects strong links in terms of vectors, but also a similarity in environmental conditions between the regions.

To date, two important vectors are known to link the west coasts of South America and South Africa; these are shipping (Faulkner et al. 2017) and the importation of oysters for aquaculture from Chile (Haupt et al. 2010). Recent work aiming to prioritise surveillance of South African ports for shipping-related introductions assessed the relative contribution of various shipping routes to South Africa's invasive species, including routes between 19 Chilean ports and South Africa (Faulkner et al. 2017). Faulkner et al. (2017) found that 50% of the 19 Chilean ports were linked to Saldanha Bay, highlighting that the potential exists for *H. helianthus* and *H. plana* (as well as the other Chilean introductions) to be introduced as larvae via ballast water or as adults through biofouling of ship niche areas such as seachests. Since neither species was detected in recent biological surveys of the bay and harbour (Peters et al. 2014; Clark et al. 2017) and the collected individuals were conspicuous and large in size, it is likely that the introduction was recent and most likely associated with hull fouling. While the potential role of local oyster farms as vectors cannot be discounted, it is very unlikely that these facilities were the source of the introductions of either species. Although oyster imports have previously been implicated in the introduction of Chilean species to the South African west coast (e.g. *T. niger* (Haupt et al. 2010)), the farms in the bay that directly import oysters from Chile bring in spat of about 2 cm. Considering the large size of the collected *H. helianthus* and *H. plana*, it seems very unlikely that they could have gone undetected in a consignment of oysters. Additionally, if they were brought in when small enough to avoid detection, it is surprising that they were not recorded previously in annual surveys of the bay (Clark et al. 2017).

The west coasts of South America and South Africa share oceanographic similarities. Both are cool temperate regions that experience coastal upwelling (Branch and Griffiths 1988; Arntz et al. 1991). Along the South African coast, the cold Benguela Current moves nutrient rich and productive waters up the west coast (Cushing 1971), while this process is driven by the Humboldt Current along the west coast of South America (Strub et al. 1998). In fact, the long-term sea surface temperature mean around Saldanha Bay (approx. 14.5 °C) falls within the range of mean temperatures experienced along the Chilean coast (approx. 13.7–15.2 °C) (Wieters et al. 2009). It is likely that the similarity in environmental conditions between these coasts has facilitated post-arrival survival of *H. helianthus* and *H. plana* in Saldanha Bay.

Due to the habitat preferences of the Chilean stone crab (Fernández and Castilla 2000), it is unlikely that this species will survive along the wave exposed rocky shores that typify the South African open coast. Sheltered habitats would, however, be at risk should the crab become established in the region. Presently, this distribution pattern is reflected in another crab invasion in this region, the European shore crab

Carcinus maenas, which is restricted to two South African harbours (Mabin et al. 2017) due to its inability to withstand wave-exposed conditions (Hampton and Griffiths 2007) and predation by native fish (Mabin et al. 2017). It is therefore hypothesised that *H. plana* may be restricted in the same way, should it become established in the region.

In contrast to *H. plana, H. helianthus* is more likely to survive along the South African coastline, as it inhabits both intertidal and subtidal environments (Gaymer and Himmelman 2008). They may be particularly protected in intertidal habitats, as studies in the native range have shown predator release at higher tidal heights (Gaymer and Himmelman 2008). This evasion of predators would enable them to outgrow the vulnerable juvenile stage, which in turn could aid their invasion success. Incidentally, predators are not strong regulators of community structure in the South African intertidal zone (Bustamante and Branch 1996), and therefore native biota could be particularly vulnerable should this species establish in natural habitats outside of harbours. Due to the generalist diet of *H. helianthus*, many native taxa would be at risk of predation by this keystone species (Navarrete and Manzur 2008), highlighting the risk of extensive impacts on native biodiversity.

Given the clear risk of introductions from the west coast of South America to the west coast of South Africa, the implications for management of marine introductions need to be considered. Whilst the only individuals of *H. heliaster* and *H. plana* detected have been successfully removed, the fact that they were introduced and survived indicates that there is a probability of reintroduction. It is, therefore, imperative that these two species be added to watchlists (i.e. a list of species that may potentially be successfully introduced into a region), not only in South Africa (see Faulkner et al. 2014 for most recent watchlist for South Africa), but in other regions that experience similar environmental conditions and shipping linkages to the west coast of South America. Due to the similarity in environmental conditions and introduction pathways between Chile and the west coast of South Africa, incoming vessels and aquaculture products should be monitored upon arrival in order to prevent potentially harmful introductions. Furthermore, regular monitoring of multiple sites within the bay would provide an opportunity for the early detection of introductions. Such early detection will increase the probability of successful management interventions should new alien species be recorded.

In conclusion, the present study is the first to report the Chilean stone crab *H. plana* and the South American multiradiate sunstar *H. helianthus* as alien species. The detection of these species outside their native range demonstrates their ability to be successfully introduced to other regions and highlights the vulnerability of Saldanha Bay to invasions from the west coast of South America. The findings of this study emphasise that matching environmental conditions appear to facilitate successful marine introductions. Therefore, it is recommended that both species should be added to watchlists in regions that experience similar environmental conditions and that receive vectors from Chile and South Africa.

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